JACOB

Investigation of the Effect Of Vacuum on the Economy Of a 5000 K. W. Turbine

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INVESTIGATION OF THE EFFECT OF VACUUM ON THE ECONOMY OF A 5000 K. W. TURBINE

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Ernst Otto Jacob

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ERNST OTTO JACOB

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

CONTENTS.

THE EFFECT OF VACUUM UPON THE ECONOMY OF A 5000 K. W. TURBINE.

I. Introduction.

That the idea of using the energy contained in a jet of steam for the production of power is an old one is evinced by the fact that Hero in the third century describes a whirling eolipile employing the reaction principle. The first impulse wheel was suggested by Branca in the 17th century, it being used for grinding and pulverizing drugs. With the beginning of the 19th century interest in these direct-action rotary motors became more and more wide-spread, the very ignorance of the nature of steam being a prominent factor in the production of versatile but usually ignorant inventors.

It is the purpose of thesis to investigate one of the many problems that present themselves to turbine designers and operators, viz., the effect of varying degrees of vacuum upon steam economy. The writer appreciates the danger of drawing conclusions from a comparatively small number of tests, but comparisons of the results obtained in other tests seem to justify the statement that these tests will indicate very clearly a percentage of correction for vacuum that may be applied to any steam turbine of large capacity.

II. Steam Turbine Development.

Among all the worthless inventions, however, there are a few whose merits really entitle them to places among the useful inventions. The first of these, the Real and Pinchon turbine was of the compound impulse type. There was one velocity stage for each préssure stage, the blades were flat and radial and the orifices were cut diagonally in the diaphragms between succeeding pressure stages. However, there was apparently no provision for the expansion of steam, all stages being of the same cylinder volume.

The Avery turbine (1831) marks the advent of the first practical reaction wheel. This machine was used extensively in running lumber mills. It had, however, an extremely high velocity, the peripheral speed sometimes reaching 14 1/2 miles a minute. Leroy followed Avery with wheels of the same type and used expanding nozzles in place of plain orifices.

Pilbrow was the first man to introduce the idea of using wheels running in opposite directions. This idea was developed to a considerable extent by such men as Babbitt, Altham and Seger but has proved more or less impracticable.

The compound reaction turbines have their inception in the invention of Wilson. He allowed the steam to flow through gradually expanding passages having alternate moving and guide vanes and his machine represents Parsons' idea in its simplest form. Other men who followed him in the development of this type are Tournaire, Monson and Parsons. Parsons first came into the turbine field in 1885 when he received a patent upon a machine much like Wilson's first motor, but having a tandem arrangement. The really new feature of his work, however, is the introduction of the Parsons bearing which, with slight improvements has come down to the present day and forms a distinctive element in the Parsons type. Parsons improved his machine from time to time, introducing in 1888 the multi-cylinder arrangement, in 1892 the condenser and in 1896 the improved Parsons governor with its characteristic puff-admission of steam. Wilson was the originator of another important type, the radial flow turbine. In this machine the steam enters at the center of the wheel and flows radially outward impinging upon various rows of guide and moving vanes during its passage. Monson's reaction wheel was also of the radial flow type though slightly different in construction from that of Wilson. Cutler further developed this principle,

but it has not been used much in recent years.

A third type conceived by the versatility of Wilson's genius was a machine having passages allowing for the return of the steam to the blades thus introducing the possibility of compounding with only one wheel. This idea was worked with considerably. It was improved upon by Hoehl, Brakell and Gunther, Perrigault and Farcot, Imray, Last and Ferranti, and has received its highest development in the patent of Stumpf. The obvious disadvantage of this type is the wide range of temperatures in the same stage.

The compound impulse turbine has proven one of the most popular types with inventors. The Hartman brothers employed it in America for the first time, following upon the suggestions of Real and Pinchon and of Tournaire. Moorehouse is one of the first, however, who made succeeding cylinders larger in order to allow for the expansion of steam with decreasing pressures. Both Breguet and Ferranti had almost the same idea as Hartman.

DeLaval took out his first patent in 1883. This was for a turbine of the Avery outward flow type having two arms with the steam escaping from a nozzle at the end. DeLaval's impulse wheel was patented in 1894. He was the first to apply the diverging nozzle to a single impulse wheel, thus

producing high tangential velocity; this he proposed to gear down to a reasonable rate. In order to produce balancing the shaft of this turbine is made of nickel steel, slightly flexible, so that the wheel may seek its own center of rotation. In 1894 the first patents relating to the use of wheels of the Pelton type were issued, one in America to J. F. McElroy, the other in England to Prof. A. Rateau. Most of the machines of this type are single wheel machines. Usually the steam is given but a single passage through the vanes, thus making the machine of the highspeed variety. In a number of cases, however, the steam is made to return upon itself by means of suitable passages, and to take a second course through the turbine.

III. Chronological table of turbine Development.

1830	Real and Pinchon--compound impulse.
1831	Avery--reaction.
1838	Leroy--reaction, used nozzles.
1842	Pilbrow--impulse;two wheels in opposite directions
1848	Wilson--compound reaction.
	--radial flow.
	--return flow.
1858	Hartman brothers--compound impulse.
1863	Hoehl, Brackell and Gunther--return flow.
1866	Perrigault and Farcot--return flow.
1879	Cutler--radial flow.
1881	Imray--return flow.
1883	DeLaval--reaction wheel.
1885	Parsons--Compound reaction.
1885	Last--return flow.
1892	Parsons--condensing reaction.
1894	DeLaval--Impulse wheel.
1894	McElroy--Pelton wheel.
1894	Rateau--Pelton wheel.
1896	Curtis--compound impulse.
1896	Parsons--Governor.
1903	Stumpf--Pelton.

IV. The Curtis turbine; events leading up to turbine adoption in Fisk Street Station.

Curtis took out his first patent in 1896 and his group of patents cover most of the basic principles of the compound impulst turbine. His first types had but one velocity stage for each pressure stage, but he soon employed two and even three. The most approved way for large powers is, at present, two velocity stages for each pressure stage with from four to six pressure stages. Admission of steam is through a series of from twelve to twenty-four nozzles arranged around the periphery of the wheel. The control of these nozzles is vested in the "piano board valve chamber" scheme of governing all valves at all in use being open full all the time, thus insuring maximum economy for the jet. A potential efficiency of 77% has been secured by the use of this machine, a record which is beaten only by one or two instances of the most refined steam engine practise. Considering the fact that almost all effective development in the steam turbine has taken place since 1885, it is certainly safe to predict a remarkable future for this type of prime mover. At least five distinct types are proving commercially successful and in each of them the extremely rapid rate of improvement suggests the probability of increased efficiency and

economy with each succeeding year of turbine construction. Thus far the Curtis compound impulse turbine is leading in the progress which is being made, but it is not by any means without its serious rivals.

In 1900 a committee appointed by the Commonwealth Electric Co., began to investigate American and European practise and attempted to determine what would be the most satisfactory and economical method of generating power for the City of Chicago. The reciprocating engine was at the height of its popularity. In Europe the poppet-valve engine using superheated steam was beginning to attract world wide attention, while American practise of large diameters and enormous size was producing results almost as good. It was about this time that the 100,000 horse-power station of the Manhattan Elevated Railway of New York City was projected and built, and the Allis-Chalmers horizontal vertical cross-compound 8000 horse-power units were doing such work as to earn for one of their class the title "Old Reliable".

However, the steam-turbine with the enormously reduced size per horse-power and the advantages accruing from the use of smaller generators at higher speeds was just at this time beginning to attract attention. In England, Parsons had invented a

machine which gavea very creditable performance under various conditions while in America the Curtis turbine has been installed in a few places in small units. The General Electric Co., however, expressed entire willingness to build turbine generator sets of 5000 kilowatt capacity with a satisfactory guarantee of performance. This type was consequently decided upon and the satisfactory results of the first unit as well as the remarkable increase in economy with each new installation shows that the confidence thus reposed was well placed.

It is with the first 5000 K. W. unit, distinguished as Fisk Street Turbine No. 1, that the series of tests herein recorded have to do.

V. Description of Fisk Street Generating Station.

The Fisk Street Generating Station of the Commonwealth Electric Co., is a plant of 52000 K. W. rated capacity. Its generators comprise four 5000 K. W. machines and four of 8000 K. W. rated load. Two additional units of 8000 K. W. capacity are now under construction and the final plans contemplate a station of fourteen units having a total rated load of 100,000 K. W. All the prime-movers are Curtis compound-impulse trubines, each turbo-generator set being independently operated by a battery of eight 500 horse-power Babcock and Wilcox water-tube boilers. 3-Phase Current is generated at 9000 volts and twenty-five cycles and the load is adjusted by the operator in the operating gallery. Fig. 1 shows a plan of the station, boiler house and switch house. The latter contains the oil switches for the electrical installation and it is from here that current is fed to the different distributing stations.

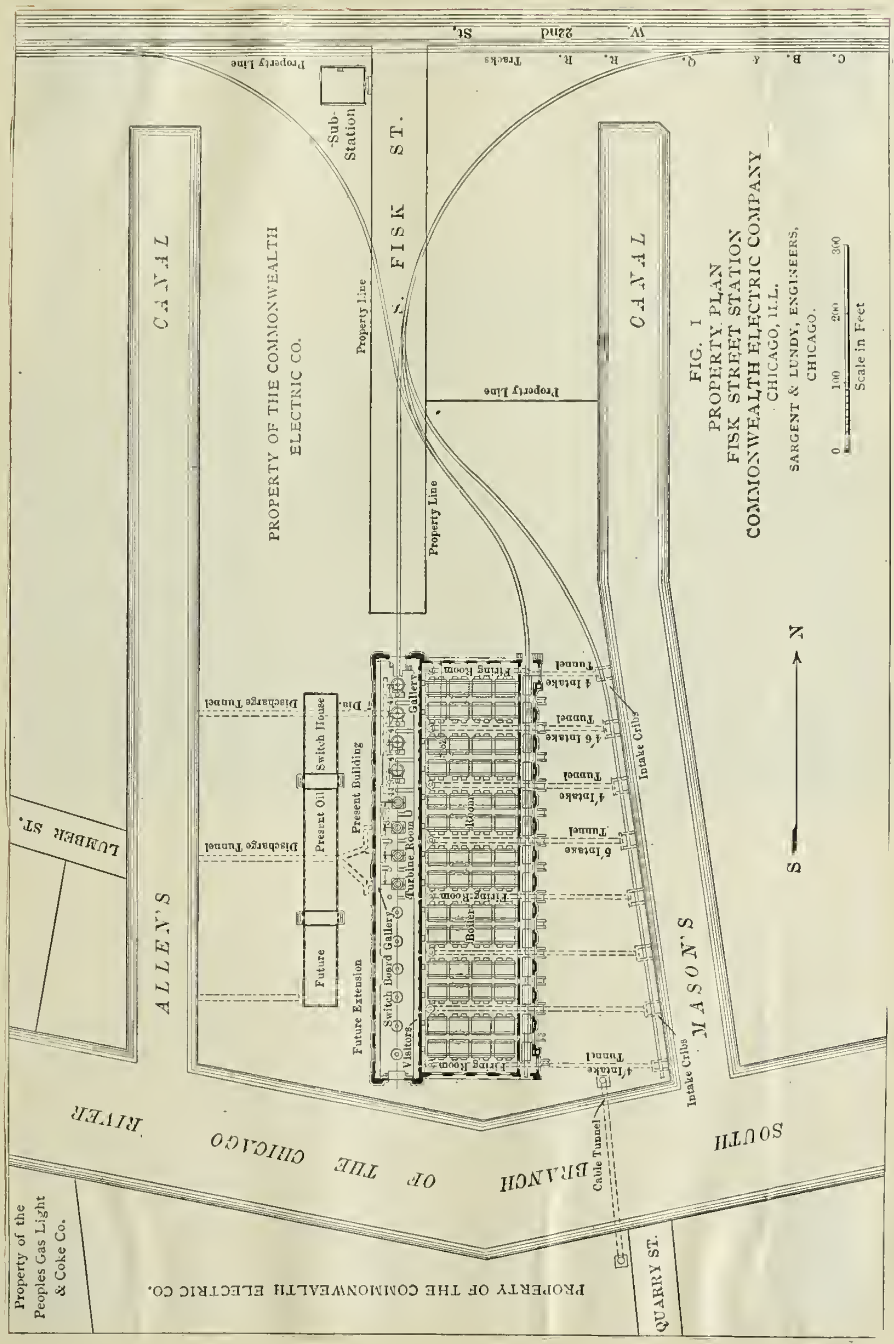


FIG. I
PROPERTY PLAN
FISK STREET STATION
COMMONWEALTH ELECTRIC COMPANY
CHICAGO, ILL.
SARGENT & LUNDY, ENGINEERS,
CHICAGO.
0 100 200 300
Scale in Feet
W. 22nd St.
C. B. & Q. R. R. Tracks
Property Line
Sub-Station
S. FISK ST.
CANAL
PROPERTY OF THE COMMONWEALTH ELECTRIC CO.
LUMBER ST.
ALLEN'S
MASON'S
Discharge Tunnel
Switch House
Present Oil
Future
Present Building
Future Extension
Switch Board Gallery
Turbine Room
Boiler Room
Firing Room
Visitors
Gallery
Intake Cribs
Tunnel
4' Intake
4' 6" Intake
6' Intake
Cable Tunnel
S
N
SOUTH BRANCH OF THE CHICAGO RIVER
Property of the Peoples Gas Light & Coke Co.
QUARRY ST.

Fig. 1.

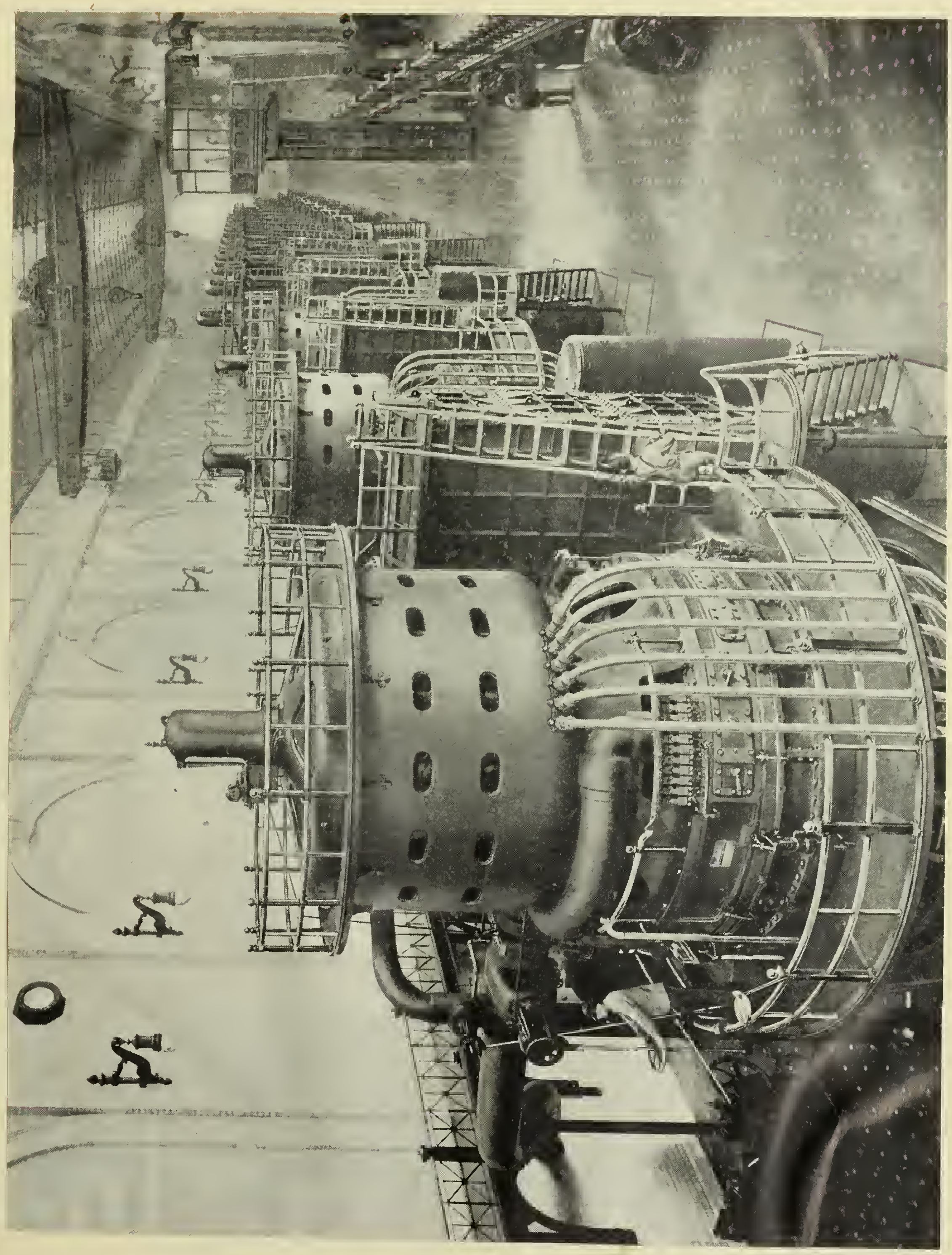


Fig. 2. Turbine Room.

VI. Tests of 5000 K. W. Turbine.

(a) Preliminary remarks.

The test described here was carried on in the Fisk Street Station of the Commonwealth Electric Co. of Chicago. It was composed of four trials, each of two hours duration, one hour's consecutive readings being chosen in each trial for the determination of results. Of these trials, trial No. 4 was carried on March 5, 1907 while trials No. 1, 2 & 3 were performed March 6, 1907. The corps of observers consisted of ten students of the senior class of the Mechanical Engineering Departments of the Universities of Illinois and of Wisconsin, several men furnished by Sargent and Lundy, consulting engineers, Chicago, and two or three of the Commonwealth Electric Company's employes.

(b) Purpose of tests.

The Purpose of this test was the determination of the effect of variations of vacuum in the condenser upon the economy of the machine. This test was to be carried on preliminary to the general load curve tests, the results derived from this test to be applied in correcting for variations of vacuum from contract specifications. It was also proposed that the effect of the variation of other general conditions be studied, and, if worthy of consideration, shown by curves.

The investigation took place at full load, namely 5000 K. W. To facilitate comparison all water rates were reduced to 200 lbs. absolute initial pressure 125 degrees, F. superheat.

(c) Method and Observations--Calibrations.

Unit No. 1 of the Fisk Street Station is a two stage machine of 5000 K. W. capacity making 500 R. P. M. It is one of the earlier types of turbine and has three velocity stages in each pressure stage. The condenser is of the Alberger counter current type, shown in Fig. 3 and has about 20000 square feet of cooling surface. The circulating water enters at the top and going through the three passes, reaches the bottom and is discharged. The steam enters at the bottom and moves upward while the condensation is collected in the bottom of the condenser, from which it is pumped by means of the hot well pump into the feed water heaters. The circulating pump is of the centrifugal type (Fig. 4) and is operated by a Corliss engine. The feed pumps Fig. 5 are of special design. Either one alone can pump all of the feed water at normal load.

As already stated, the trials were carried on in two hour runs, general and turbine observations being taken every four minutes while electrical

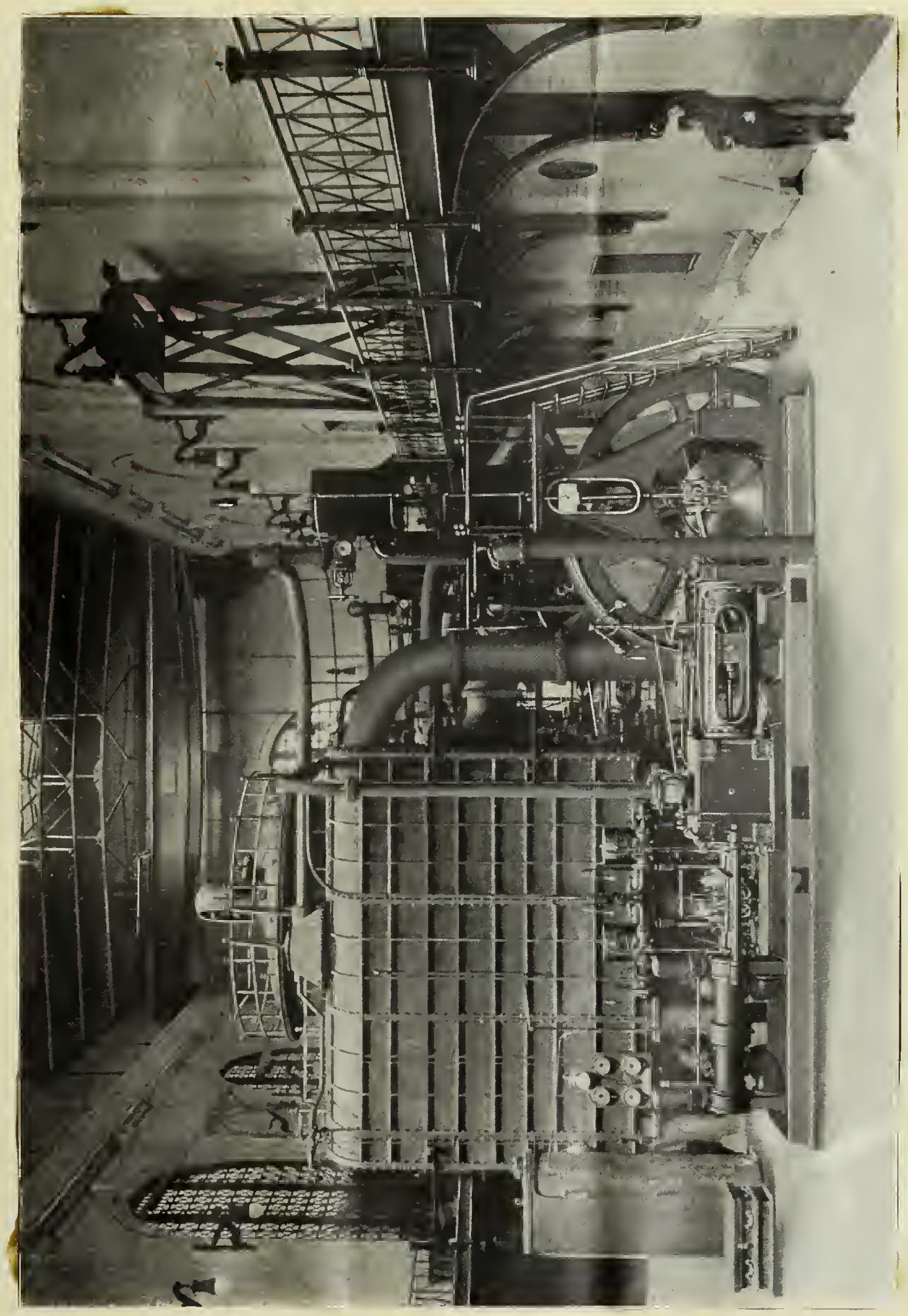


Fig.3. Alberger Condensing Apparatus

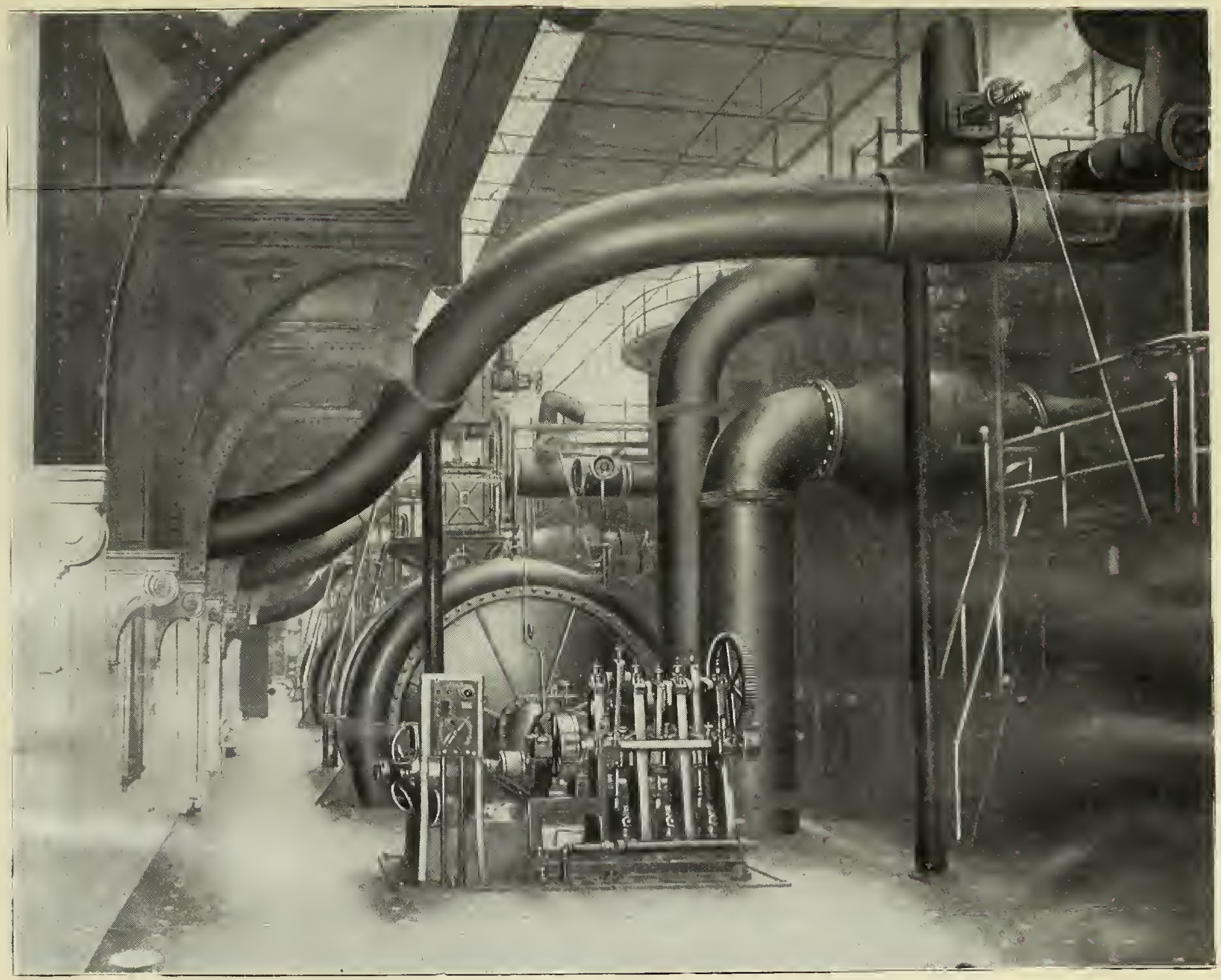


FIG. 4. CIRCULATING PUMP

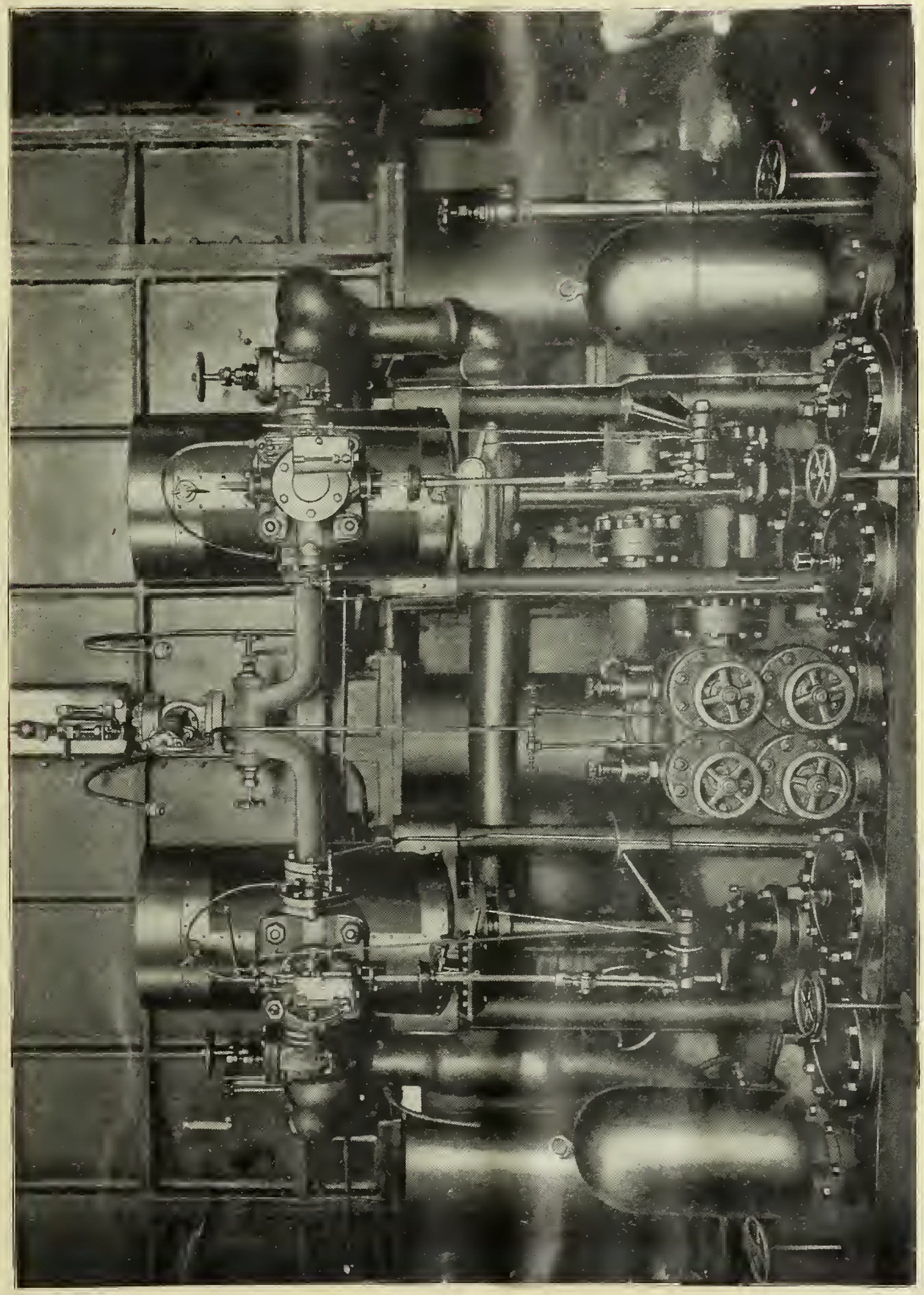


Fig. 5. Feed Water Pumps

readings were taken every two minutes. Signals were given by electrical bells which rang simultaneously at the turbine, on the operating gallery and in the switch-house, the intervals being controlled by the time-keeper in the switch-house. The load was controlled by a special operator in the operating gallery and was maintained fairly constant. All observations were carried on in the same order in which they were begun, thus insuring fairly constant intervals for the different readings.

All thermometers and other accessory apparatus were carefully calibrated by comparison with certified standards. The condenser pressures were measured by Hohmann and Maurer mercury columns. The high pressure gages were calibrated after each trial while still hot and corrections applied to the readings from the resulting calibration curves. Electrical instruments were calibrated by comparison with standards having certificates from the National Bureau of Standards at Washington, D. C. Scales were tested by Factory and City of Chicago inspectors and were found to be correct. The water weighing apparatus is shown in its general scheme in Fig. 6. This arrangement proved very accurate and easy to operate. The quick-opening valves were largely responsible for the rapidity of the work.

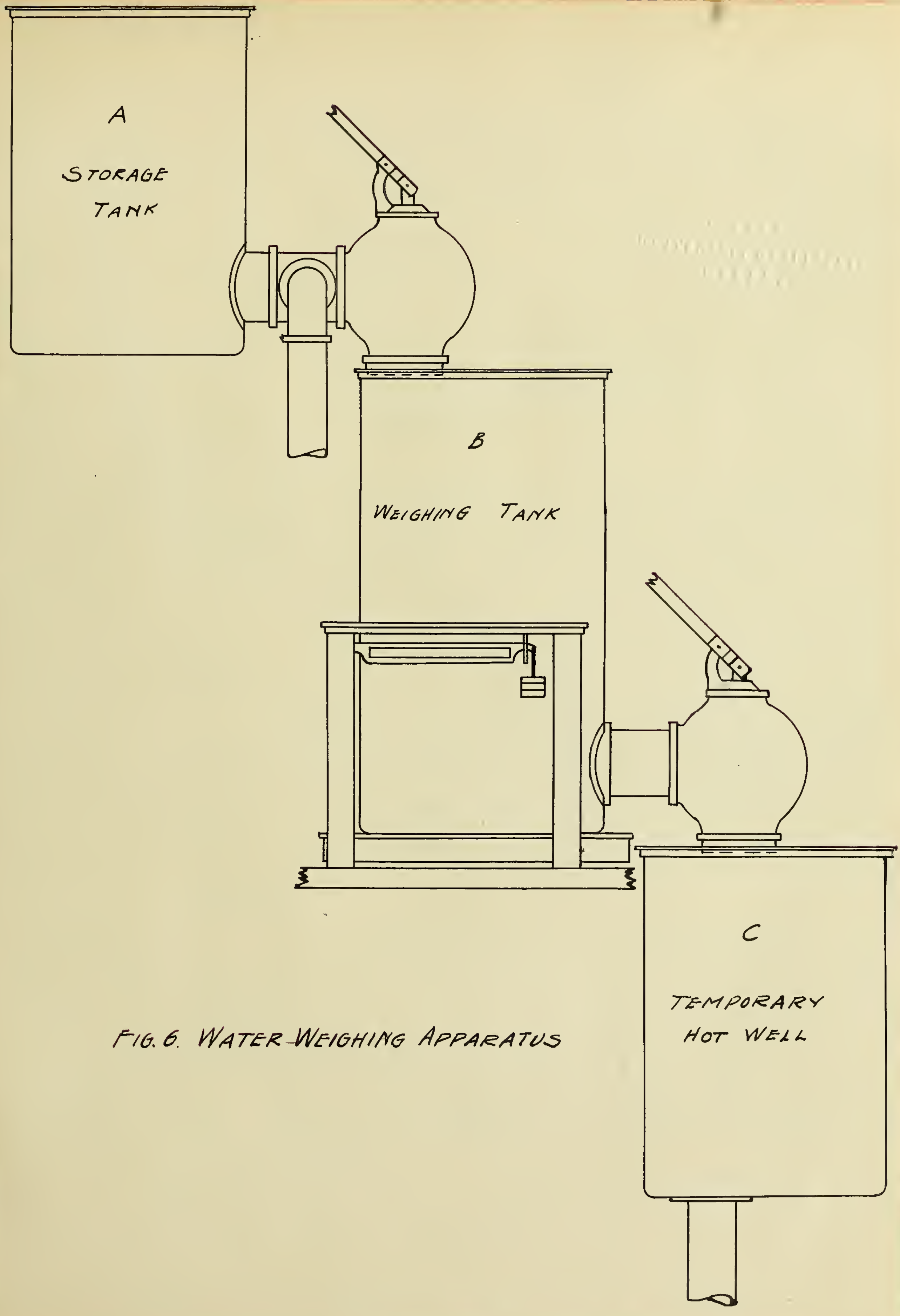


FIG. 6. WATER-WEIGHING APPARATUS

The Observations were classed as follows:

1. General readings, not entering into calculations.
2. Pressures.
3. Temperatures.
4. Corliss engine data.
5. Electrical readings.
6. Condensation.

General readings were taken, not because of any immediate relation to the test in hand, but because they are very useful for comparison.

Pressure readings were taken at all important points in the steam distribution.

Temperature readings were taken at all points corresponding to those where pressures were secured. Besides these and the general temperatures readings, however, reading of circulating water and hot well were also included.

Many of the electrical readings actually taken partook of the nature of general readings and, while useful for checking purposes did not in any way enter into the computation of the results of the Test. They are accordingly not included in this list of observations.

GENERAL OBSERVATIONS.

Outside Temperature.

Turbine Room Temperature.

Switch House Temperature.

PRESSURES.

Steam in Valve Chamber.

Steam in Bowl.

Steam in First Stage Shell.

Steam in Second Stage Shell.

Steam in Third Pass.

Steam in Second Pass.

Steam in First Pass.

Steam at Auxiliaries.

Atmospheric pressure.

TEMPERATURES.

Steam in Valve Chamber.

Steam in Bowl.

Steam in First Stage Shell.

Steam in Second Stage Shell.

Steam in Third pass.

Steam in Second Pass.

Steam in First Pass.

Water in Hot well.

Circulating Water, Initial.

Circulating Water, Final.

Steam to Auxiliaries.

Condensation.

Turbine flow.

Auxiliary flow.

Corliss Engine Data.

R. P. M.

Indicator cards.

Electrical Readings.

Excitation volts.

Excitation amperes.

Frequency.

Power Factor.

Portable Instruments, switch-house.

Condenser Leakage

CALCULATED DATA.

Pressures.

Absolute pressure in third Pass.

Absolute pressure in second Pass.

Absolute pressure in first Pass.

Press in second pass to 30" Barometer Reading.

Superheat.

Degrees superheat in Bowl.

Degrees superheat in first Stage Shell.

Degrees superheat in second Stage Shell.

Degrees superheat to auxiliaries.

R. P. M. of Turbine.

Piston speed of Corliss.

I. H. P. of Corliss.

Kilowatt, meter "A".

Kilowatt, meter "B".

Kilowatt Total.

Kilowatt, excitation.

Kilowatt net for unit.

Steam flow per K. W. Hr. (actual)

Steam flow per K. W. Hr. (corrected)

Steam flow per E. H. P. Hr. (corrected)

Auxiliary Flow % Turbine.

Auxiliary Flow Kilowatt Hr.

CORRECTIONS.

All instrumental readings were corrected according to their respective calibration curves before being put upon the final log sheets.

The steam flow was corrected for condenser leakage by means of the data secured from condenser leakage tests. These tests were performed as follows: After the close of a trial the load was taken of the machine and with no steam entering the turbine the auxiliaries were operated at the given vacuum. The water flow was of course, due only to leakage in the condenser.

Corrections for superheat and pressure will be discussed under "Computations".

(d) Sample Computations.

Absolute pressures in the condenser were found by substracting the observed vacuum readings from the barometric readings. In the case of the pressure in the second pass the vacuum to the base of 30" atmospheric pressure was found by one of two methods (a) substracting the absolute pressure from 30 inches; (b) adding to the observed vacuum the difference between 30' and the actual observed atmospheric pressure readings.

Superheats were calculated by mean curves of pressure and temperature based upon Peabody's

Steam Fables. The temperature corresponding to a given pressure being found, the difference between the actual temperature of the steam and the calculated value for saturated steam gave the degree of superheat.

The revolutions per minute of the turbine were found by multiplying the frequency by a constant depending upon the number of poles of the machine.

$$\frac{F \times 120}{n} = N$$

The piston speed of an engine is expressed by the following formula: $s = \frac{l \times 2 \times N}{12}$ when l is the stroke in inches and N represents the revolutions per minute of the machine. Having given the piston speed and mean effective pressure on piston found by means of the indicated card, the indicated horse-power ca- be derived from the following equation: $I.H.P. = \frac{PASl}{33000}$ when P is the mean effective pressure, l Sq. in. A is the area in square inches, S is the piston speed in feet per minute.

The sum of the readings of the two watt-meters "A" and "B" gives the total power in the circuit.

Steam Flow. The water rate of any machine using steam is the amount of water evaporated into steam to a given temperature, pressure and degree of superheat, which is necessary to produce a unit of work in an hour. The method of determination used in this test was to multiply the average steam flow reading by 15, thus getting the flow per hour. This

weight was divided by the net output giving the water rate in pounds per kilowatt hour. In obtaining the corrected water rate, that is the water rate applied to 200 lbs. absolute pressure and 125 F. superheat, the curves, Figures 7 and 8, were used and corrections applied as determined by the relative positions of the actual and contract points. Superheat was corrected for by assuming that 15 F. of superheat affect a gain of 1% in the water rate.

Example:

Reading No. 3 Test No. I Trial No. 4.

2:04 P. M. March 5, 1907.

Pressure in second pass 29.52-28.24=1.28" Hg.

Pressure to 30" Hg. 30"-1.28=28.72"Hg.

Superheat bowl 511.5-377.5=134°F.

Turbine speed $= \frac{25 \times 120}{6} = 500$ R.P.M.

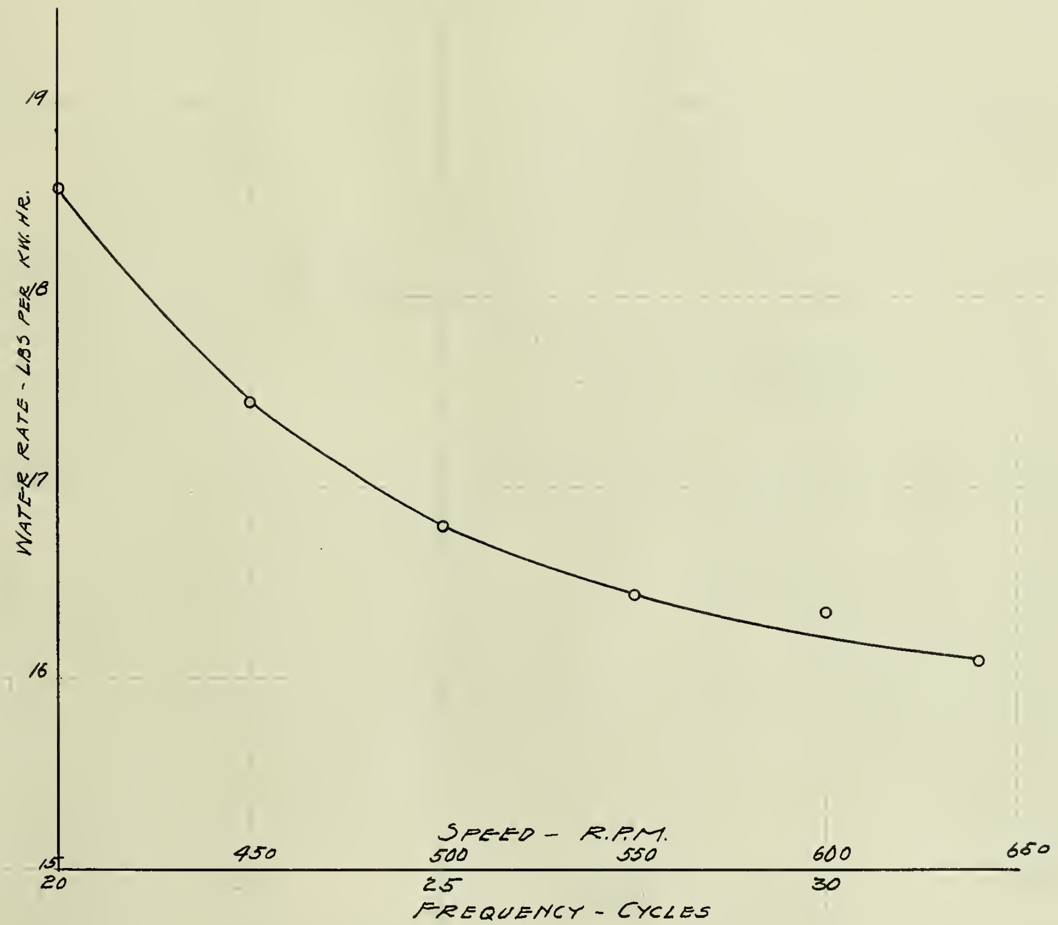
Corliss piston speed $= \frac{30 \times 2 \times 69}{12} = 345$ Ft. per min

Corrected water rate $= \frac{.2577 \times 14}{15} + 25.77 - .06 = 25.95$

(e) Discussion of Results.

These tests were carried on early in the year and the effect of the circulating water was much more beneficial, due to its coolness, than could be expected during the summer. Owing to the fact that there was superheat in the condenser even at this temperature the gain in operation during the winter is lessened considerably. Condenser leakage proved to be, as before stated, a troublesome factor, but the condenser

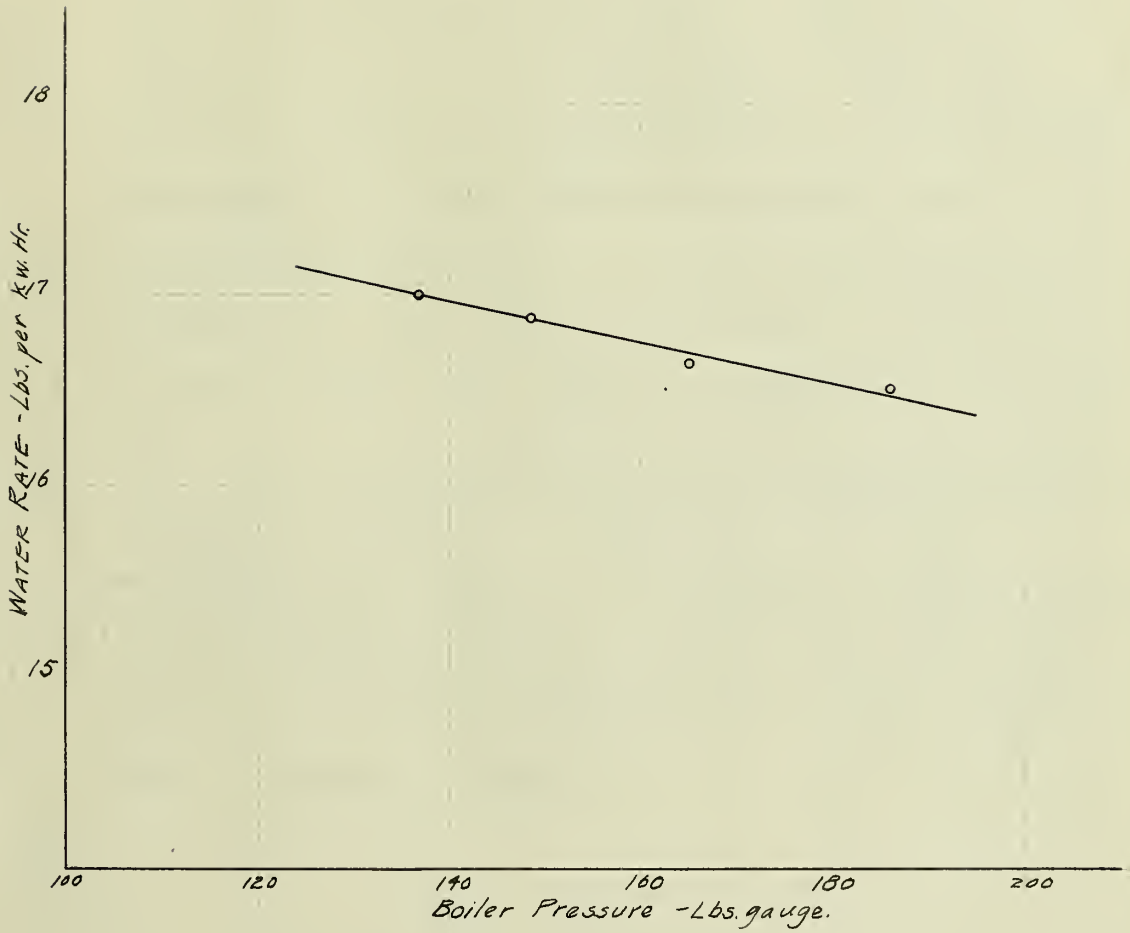
FIG. 8. 5000 K.W. SPEED CURVE



NOTE - ALL VALUES OF WATER RATE CORRECTED FOR CONDENSER LEAKAGE

TEST Nº 2.
5000 K.W. SPEED CURVE

FIG. 7. BOILER PRESSURE CURVE



NOTE.— ALL VALUES OF WATER RATE CORRECTED FOR CONDENSER LEAKAGE

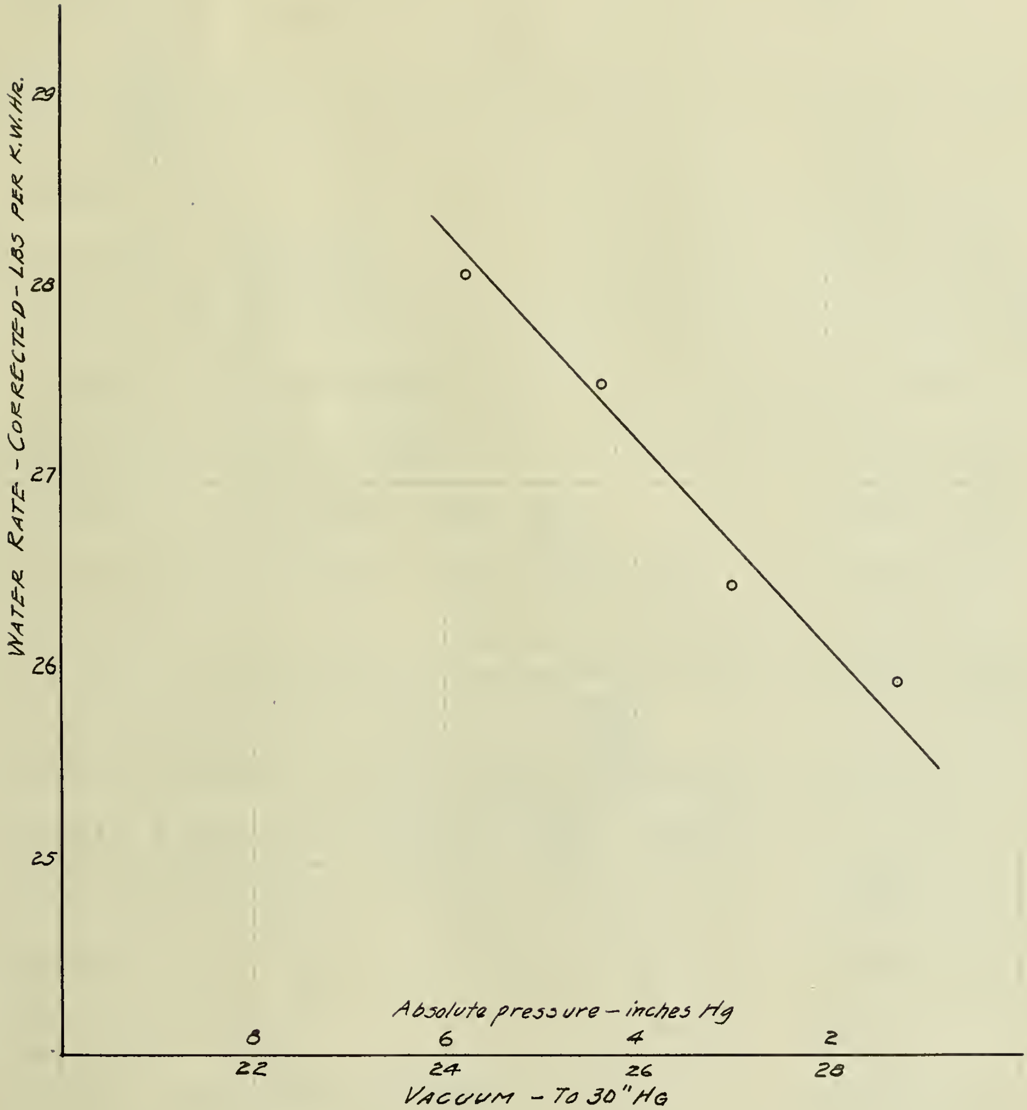
TEST Nº 2
BOILER PRESSURE CURVE

leakage tests gave such uniform results that the corrections applied may be accepted as being accurate.

(f) Conclusions.

The effect of the variations of vacuum upon the water rate of this unit is shown graphically by means of the vacuum curve, Fig. 9. This seems to indicate that for a moderate range at least the economy varies directly as the vacuum. The effect of variations in cooling water temperature could not be studied since the variation in all trials was but a few degrees. The results of the test, however, seem to indicate the great gain to be derived by carrying the vacuum as high as possible. While the gain in water rate in trial 4 as compared with trial 1 is more than 2 lbs. there is practically no difference in the auxiliary steam flow, thus showing that the gain in the turbine is not at the expense of power used in the auxiliaries.

FIG. 9. VACUUM CURVE



TEST NO. 2
VACUUM CURVE
TURBINE UNIT NO. 1

SUMMARY

TEST OF TURBINE UNIT NO. 1.

TEST NO. I.	TRIAL NO. 1.
Trial Began	10:56 A.M. 3-6-07
Trial Ended	12:00 M.
Average Load	Full Load
Atmospheric Pressure	29.83" Hg.
Initial Bowl Pressure	174 Lbs. Gage
Pressure in First Stage	3.7 Lbs. Gage
Pressure in Second Stage	23.8" Hg.
Pressure in Condenser, Ins. Hg.	24.0" Hg.
Pressure in Condenser, Ins. Hg. A.B.S.	5.78" Hg.
Pressure in Condenser, Ins. Hg. to 30"Bar.	24.22" Hg.
Degrees Superheat, Initial Pressure	136.7 F.
Degrees Superheat, First Stage Pressure	122.8 F.
Degrees Superheat, Second Stage Pressure	72.2 F.
Turbine R. P. M.	505
Excitation, K. W.	13.8
Net Output, K. W.	4763
Average Steam Flow (4 min.)	8879 lbs.
Flow per K. W. Hr.	27.96 lbs.
Flow per K. W. Hr. Corrected (To Contract)	28.09 Lbs.
Flow per E. H. P. Hr. Corrected.	20.97 lbs.
Auxiliary Steam Flow (4 Min.)	284.9 lbs.
Auxiliary Steam Flow per K. W. Hr.	.904 lbs.

SUMMARY

TEST OF TURBINE UNIT NO. 1.

TEST NO. I.	TRIAL NO. 2.
Trial began	12:48 P.M. 3-6-07.
Trial Ended	1:52 P. M.
Load	Full Load
Atmospheric Pressure	29.72" Hg.
Bowl Pressure	176 lbs.Gage
Pressure in First Stage	1.67 lbs. Gage
Pressure in Second Stage	25.13" Hg.
Pressure in Condenser	25.37" Hg.
Pressure in Condenser, ABS	4.35" Hg.
Pressure in Condenser to 30" Bar.	25.59" Hg.
Degrees Superheat, Initial Pressure	138 F.
Degrees Superheat, First Stage	126 F.
Degrees Superheat Second Stage	68.7 F.
Turbine R. P. M.	504
Excitation, K. W.	13.6
Net Output, K. W.	4772
Average Steam Flow (4 Min.)	8697 lbs.
Flow per K. W. Hr.	27.34 "
Flow per K. W. Hr. Corrected (To Contract)	27.50 "
Flow per E. H. P. Hr. Corrected	20.52 "
Auxiliary Steam Flow (4 min.)	276.3 "
Auxiliary Steam Flow per K. W. Hr.	.874 "

SUMMARY

TEST OF TURBINE UNIT NO. 1.

TEST NO. I.	TRIAL NO. 3.
Trial Began	2:00 P. M. 3-6-07
Trial Ended	3:00 P. M.
Average Load	Full Load
Atmospheric Pressure	29.70" Hg.
Initial Bowl Pressure	175.9 lbs. Gage
Pressure in First Stage	1.4 lbs. Gage
Pressure in Second Stage	26.41" Hg.
Pressure in Condenser	26.69" Hg.
Pressure in Condenser, Abs.	3.01" Hg.
Pressure in Condenser to 30" Bar.	26.99" Hg.
Degrees Superheat, Initial Pressure	140.7 F.
Degrees Superheat, First Stage	128.3 F.
Degrees Superheat Second Stage	74.3 F.
Turbine, R. P. M.	756.2
Excitation, K. W.	13.7
Net Output, K. W.	4780
Average Steam Flow (4 Min.)	8371 lbs.
Flow per K. W. Hr.	26.27 lbs.
Flow per K. W. Hr. Corrected (To Contract)	26.46 lbs.
Flow per E. H. P. Hr. Corrected	19.74 lbs.
Auxiliary Steam Flow (4 min.)	314.7 lbs.
Auxiliary Steam Flow per K. W. Hr.	.99 Lbs.

SUMMARY

TEST OF TURBINE UNIT NO. 1.

TEST NO. I.	TRIAL NO. 4.
Trial Began	1:56 P.M. 3-5-07
Trial Ended	2:56 P. M.
Average Load	Full Load
Atmospheric Pressure	29.52" Hg.
Initial Bowl Pressure	176 lbs. Gage
Pressure in First Stage	3.5 lbs. Gage
Pressure in Second Stage	27.87" Hg.
Pressure in Condenser	28.24" Hg.
Pressure in Condenser, Abs.	1.28" Hg.
Pressure in Condenser to 30" Bar.	28.72" Hg.
Degrees Superheat, Initial Pressure	139 F.
Degrees Superheat, First Stage	115 F.
Degrees Superheat, Second Stage	73 F.
Turbine, R. P. M.	500
Excitation, K. W.	14.0
Net Output, K. W.	4921
Average Steam Flow (4 min.)	8452 lbs.
Flow per K. W. Hr.	25.77 lbs.
Flow per K. W. Hr. Corrected (To Contract)	25.95 lbs.
Flow per E. H. P. Hr. Corrected	19.37 lbs.
Auxiliary Steam Flow (4 min.)	290 lbs.
Auxiliary Steam Flow per K. W. Hr.	.79 lbs.

MMONWEAL | STA CHICAGO
OF TUR | OF TRIAL VACUUM CURVE - 5000 K.W.
ACUUM UP | AL CONDITIONS Barometer 29.83"
Vacuum 23.9"

HEAT			REMARKS
1ST	2ND	STEAM TO AUX	
121.	66.	126	WATER RATES CORRECTED FOR CONDENSER LEAKAGE
119.	68.	126.	
121.	67.	128.	
124.	73.	130.	
121.	74.	132.	
125.	75.	132	
125.	77.	131.	
123.	72	130.	
122.	70.	129.	
121.	68.	128.	
121.	71.	129.	
123.	73.	131.	
125.	75.	131.	
125.	76.	130	
125.	73.	129.	
124.	75.	132.	
121.	75.	131.	
122.8	72.2	129.8	

Trial 1
MARCH 6, 1907
10.56 A.M.
12.00 M.

COMMONWEALTH ELECTRIC CO.
TEST OF TURBINE UNIT Nº 1
INVESTIGATION OF THE EFFECT OF VACUUM UPON THE ECONOMY OF A 5000 K.W. T

Vacuum Curve - 5000 K.W.
Barometer 29.83"
Vacuum 23.9"

ALL WATER RATES CORRECTED FOR CONDENSER LEAKAGE

No.	Time	PRESSURES: Turbine		#□"	Condenser (In Hg)								
1	10.56	175	174	4.0	23.8	24.0	5.83	24.0	5.83	24.17	24.0	5.83	176
2	11.00	175	174	3.4	23.9	24.1	5.73	24.1	5.73	24.27	24.1	5.73	176
3	.04	173	172	5.0	23.7	23.9	5.93	24.0	5.83	24.17	23.9	5.93	175
4	.08	173	172	4.0	23.9	24.0	5.83	24.1	5.73	24.27	24.0	5.83	175
5	.12	175	173	4.5	23.8	23.9	5.93	24.0	5.83	24.17	24.0	5.83	176
6	.16	177	175	3.4	23.9	24.0	5.83	24.1	5.73	24.27	24.1	5.73	178.5
7	.20	178	177	3.5	24.1	24.2	5.63	24.3	5.53	24.47	24.3	5.53	178.5
8	.24	178	176	3.5	23.9	24.0	5.83	24.0	5.83	24.17	24.0	5.83	179.5
9	.28	177	174	3.4	23.8	23.9	5.93	24.0	5.83	24.17	24.0	5.83	179.5
10	.32	173	169	4.5	23.6	23.8	6.03	23.9	5.93	24.07	23.8	6.03	175.
11	.36	173	171	4.5	23.9	24.0	5.83	24.1	5.73	24.27	24.1	5.73	174.5
12	.40	176	173	3.4	24.0	24.1	5.73	24.2	5.63	24.37	24.2	5.63	176.
13	.44	178	175	3.5	24.1	24.2	5.63	24.3	5.53	24.47	24.2	5.63	179.5
14	.48	178	175	3.5	24.0	23.8	6.03	23.9	5.93	24.07	23.8	6.03	178.5
15	.52	178	176	3.5	23.7	23.8	6.03	23.9	5.93	24.07	23.9	5.93	179.5
16	.56	173	174	3.0	23.9	24.0	5.83	24.0	5.83	24.17	24.0	5.83	178.5
17	12.00	180	178	3.4	23.8	23.8	6.03	23.9	5.93	24.07	23.9	5.93	179.5
Ave.		175	174	3.7	23.8	23.9	5.87	24.0	5.78	24.22	23.9	5.87	177.4

No.	TEMPERATURES: Turbine		Condenser			Hot Well		Cir Water Initial	Cir Water Final	Steam to Air	SUPERHEAT: Turbine				SPEED: Turbine Freq	R.P.M.
1	491	345	207	50	111	142	136	34.8	63.0	504	114.2	121.	66.	126.	25.25	505
2	510	342	208	49	108.5	142	135	34.8	63.0	504	133.	119.	68.	126.	25.25	505
3	515	348	209	50	109.	143	138	34.8	63.0	505	139.	121.	67.	128.	25.25	505
4	517	348	213	50	106.	141.5	134	34.8	63.0	507	141.	124.	73.	130.	25.25	505
5	520	347	215	50	105.	142.	136	34.7	62.0	510	144.	121.	74.	132.	25.25	505
6	520	348	215	50	106	141	135.5	34.8	62.0	511	143.	125.	75.	132.	25.25	505
7	518	348	214	51	110	141	134	34.8	63.0	511	140.	125.	77.	131.	25.25	505
8	512	346	212	51	106	142	136	34.8	62.0	509	134.	123.	72	130.	25.25	505
9	511	345	211	51	106	142.5	135	34.8	62.0	508	134.	122.	70.	129.	25.25	505
10	511	347	212	51	109	144	136	34.8	62.5	507	136.	121.	68.	128.	25.25	505
11	510	347	211	51	114	140	135	34.8	63.0	506	135.	121.	71.	129.	25.25	505
12	514	346	211	51	107	141	135	34.8	62.0	506	138.	123.	73.	131.	25.25	505
13	516	348	212	52	109	140	134	34.8	62.0	509	139.	125.	75.	131.	25.25	505
14	517	348	214	51	106	143	136	34.8	62.0	510	140.	125.	76.	130	25.25	505
15	518	348	215	51	104	143	136	34.8	62.0	510	140.	125.	73.	129.	25.25	505
16	515	345	215	52	104	142	136	34.8	62.0	511	138.	124.	75.	132.	25.25	505
17	515	344	216	52	101	134	137	34.7	58.0	510	136.	121.	75.	131.	25.25	505
Ave.	513	346	212	50.7	107	132	135	34.8	62.1	508	136.7	122.8	72.2	129.8	25.25	505

KILOWATTS: Time	2 Meter Method A	B	Total	Excitation				Steam Turbine	
10.56	2348	2563	4911	120	115	13.8	4897		
.58	2324	2464	4793						268.6
11.00	2277	2446	4723	120	115	13.8	4744		
.02	2348	2469	4811					9095	268.6
.04	2301	2469	4770	120	115	13.8	4776		
.06	2348	2493	4841					9180	244.0
.08	2324	2464	4793	119	115	13.6	4803		
.10	2277	2399	4676					8735	244.0
.12	2277	2399	4676	120	115	13.8	4662		
.14	2277	2422	4699					9000	244.0
.16	2277	2446	4723	120	115	13.8	4697		
.18	2348	2443	4841					8790	245.6
.20	2348	2493	4841	120	115	13.8	4827		
.22	2324	2493	4817					8680	245.6
.24	2324	2446	4770	120	115	13.8	4779		
.26	2324	2446	4770					9135	245.6
.28	2301	2446	4747	120	115	13.8	4744		
.30	2277	2446	4723					8795	279.6
.32	2371	2446	4817	120	115	13.8	4756		
.34	2371	2540	4911					8575	279.6
.36	2371	2563	4934	120	115	13.8	4908		
.38	2371	2493	4864					9060	279.6
.40	2301	2446	4767	120	115	13.8	4801		
.42	2324	2446	4770					9270	279.0
.44	2324	2422	4746	121	115	13.9	4744		
.46	2324	2422	4746					8690	279.0
.48	2301	2493	4794	120	115	13.8	4768		
.50	2348	2493	4841					9040	279.0
.52	2324	2469	4793	120	115	13.8	4803		
.54	2324	2469	4793					8450	287.3
.56	2301	2399	4700	121	116	14.0	4732		
.58	2207	2164	4371					8905	287.3
12.00	2324	2399	4723	121	116	14.0	4533	8665	287.3

Ave.: 4773 120 115.0 13.8 4763 8879 27.96 28.09 2097 284.9 3.22 .904

...S STA. CHICAGO ILL

...T OF TRIAL VACUUM CURVE

...UAL CONDITIONS 5000 K.W.

Vacuum 25,59"

...HEAT			REMARKS
	1ST	2ND	
7.	123.	51.	Barometer 29.72"
8.	123.	66.	Outside TEMP 28.2°F.
7.	122.	68.	Switch House ,, 75° F.
8.	122.	65.	Total Steam Flow 139150 Lbs.
5.	125.	61.	Aux. ,, ,, 4421 Lbs.
7.	121.	67.	WATER RATES CORRECTED FOR
	124.	73.	CONDENSER LEAKAGE
4.	127.	75.	
3.	127.	76.	
	132.	74.	
7.	132.	74.	
4.	125.2	73.	
	125.2	71.	
6.	129.0	68.	
4.	128.	68.	
5	128.	68.	
5	12.8.	70	
8.	126.	68.7	

TURBINE UNIT No. 1

INVESTIGATION OF THE E... IN THE ECONOMY OF A 5000 K.W.

MARCH 6, 1907
12.48 P.M.
1.52 P.M.

VACUUM CURVE
5000 K.W.
Vacuum 25.59"

PRESSURES

No.	Time					2nd Pass					
1	12.48	180	1.78	1.25	24.85	24.46	5.26	24.73	24.45	5.27	181.
2	.52	183	180	1.70	24.65	25.65	4.07	25.92	25.64	4.08	182.5
3	.56	180	178	1.40	25.10	25.37	4.35	25.58	25.30	4.42	182.5
4	1.00	177	173	1.80	25.10	25.30	4.42	25.52	25.24	4.48	175.5
5	.04	177	173	1.75	25.25	25.30	4.22	25.70	25.42	4.30	175.0
6	.08	179	176	1.55	25.25	25.50	4.23	25.71	25.43	4.29	180.0
7	.12	181	178	1.16	25.25	25.44	4.24	25.72	25.44	4.28	182.
8	.16	178	175	1.55	25.25	25.48	4.25	25.69	25.41	4.31	180.
9	.20	174	171	1.70	25.15	25.47	4.34	25.56	25.28	4.44	174.5
10	.24	177	175	1.70	25.10	25.38	4.33	25.56	25.28	4.44	175.5
11	.28	178	177	1.90	25.20	25.37	4.28	25.64	25.37	4.35	181.
12	.32	178	178	1.90	25.05	25.44	4.44	25.50	25.22	4.50	180.5
13	.36	179	178	1.80	25.30	25.28	4.15	25.77	25.49	4.23	181.
14	.40	179	178	1.80	25.25	25.57	4.22	25.70	25.42	4.30	182
15	.44	178	178	1.80	25.15	25.50	4.34	25.58	25.30	4.42	180.5
16	.48	177	178	1.80	25.10	25.38	4.43	25.49	25.21	4.51	180.
17	.52	175	174	1.75	25.15	25.34	4.38	25.57	25.29	4.43	174.5
		178	176	1.67	25.13	25.37	4.35	25.59	25.31	4.42	179.2

TEMPERATURES

No.	Turbine			Condenser		Hot Well	Cir. Water Initial	Final	To Air
1	516	336	184	115	138	126	34.6	61.	504
2	517	337	200	117	126	126	34.8	62.	506
3	512	335	199	111	133	126	34.8	61.	506
4	514	339	196	110	129	127	34.7	62.5	504
5	512	338	191	118	130	125	34.7	62.	501
6	513	340	196	119	130	125	34.6	61.	502
7	521	341	202	116	130	125	34.6	61.	507
8	520	346	205	112	130	125	34.6	60.5	511
9	519	346	206	117	130	126	34.6	61.	512
10	520	346	205	118	130	126	34.6	62.	512
11	520	335	204	119	131	125	34.6	62.	513
12	517	345	204	121	132	127	34.8	62.	511
13	512	342	200	119	131	124	34.8	62.5	510
14	509	343	198	120	130	125	35.0	62.	508
15	512	342	198	121	130	126	34.8	62.5	507
16	513	342	199	120	132	127	34.8	62.	507
17	513	342	200	118	130	126	35.0	62.	506
	515	341	199	117	131	126	34.7	61.7	507

SPEED

No.					Turbine Freq.	Turbine R.P.M.	Corliss R.P.M.	Corliss Ft/Min	I.H.P. Corliss
1	138.	123.	51.	124.	25.30	506	69.3	356.3	78.4
2	138.	123.	66.	126.	25.25	505	69.3	356.3	88.6
3	134.	122.	68.	126.	25.25	505	69.3	356.3	79.6
4	138.	122.	65.	127.	25.25	505	69.0	345.	85.2
5	136.	125.	61.	124.	25.21	504	69.0	345.	83.9
6	142.	121.	67.	123.	25.20	504	69.0	345.	76.0
7	144.	124.	73.	127.	25.20	504	69.3	356.3	79.2
8	144.	127.	75.	132.	25.25	505	69.3	356.3	81.0
9	143.	127.	76.	135.	25.20	504	68.7	343.8	80.9
10	142.	132.	74.	135.	25.20	504	68.7	343.8	80.1
11	139.	132.	74.	133.	25.20	504	68.7	343.8	76.5
12	134.	125.2	73.	132.	25.20	504	68.7	343.8	79.4
13	131.	125.2	71.	130.	25.20	504	69.0	345.	81.1
14	136.	129.0	68.	129.	25.20	504	69.0	345.	82.4
15	134.	128.	68.	128.	25.15	503	68.7	343.8	82.2
16	135.	128.	68.	128.	25.15	503	68.7	343.8	81.7
17	145.	128.	70	129.	25.15	503	68.7	343.8	80.0
	138.	126.	68.7	128.	25.21	504	68.90	344.9	80.4

KILOWATT / STEAM FLOW

No.	Time	2 Meter A	B						Turbine				Aux. K.W.H.	Total	% Tur.
1	12.48 .50	2301 2254	2446 2399	4747 4653	119	114	13.6	4733							
2	.52 .54	2348 2254	2610 2446	4958 4700	119	114	13.6	4944	7865					312	
3	.56 .58	2254 2230	2446 2375	4700 4605	118	114	13.5	4687.	8915.					312	
4	1.00 .02	2324 2324	2540 2563	4864 4887	117	113	13.2	4851.	8825.					313	
5	.04 .06	2277 2301	2493 2516	4770 4817	118	113	13.3	4757.	9150.					222	
6	.08 .10	2301 2272	2516 2493	4817 4770	119	114	13.6	4803.	8810.					222	
7	.12 .14	2277 2277	2469 2469	4746 4746	120	114	13.7	4732.	8680.					222	
8	.16 .18	2254 2230	2446 2399	4710 4629	119	114	13.6	4686.	8660					295	
9	.20 .22	2254 2277	2399 2469	4653 4746	119	114	13.6	4634.	8490					295	
10	.24 .26	2301 2324	2469 2516	4770 4840	118	115	13.6	4756.	8680					295	
11	.28 .30	2348 2324	2587 2493	4935 4817	119	115	13.7	4921.	8765					284	
12	.32 .34	2324 2324	2493 2540	4817 4864	119	116	13.7	4803.	8825					284	
13	.36 .38	2348 2348	2540 2563	4888 4911	118	115	13.6	4874.	8680					284	
14	.40 .42	2348 2324	2540 2540	4888 4864	119	115	13.7	4874.	9005					288	
15	.44 .46	2301 2254	2516 2516	4817 4770	118	115	13.6	4803	8690					288	
16	.48 .50	2277 2277	2493 2469	4770 4746	118	115	13.6	4756	8740					288	
17	.52	2277	2446	4723	118	115	13.6	4709	8670					217	
				4786	119	114	13.6	4712	8697	27.34	27.50	20.62	.874	276	33.18

REMARKS

Barometer 29.72"
Outside Temp 28.2° F.
Switch House " 75° F.
Total Steam Flow 139150 Lbs.
Aux. " " 4421 Lbs.
ALL WATER RATES CORRECTED FOR CONDENSER LEAKAGE

FISK ST. STA. CHICAGO ILL.

OBJECT OF TRIAL VACUUM CURVE

GENERAL CONDITIONS 5000 K.W.

26.5" Vacuum Barometer 29.70" Hg.

REMARKS

OUTSIDE TEMPERATURE 30°F

SWITCH HOUSE " 75°F

TOTAL STEAM FLOW 125,560#

TOTAL AUX. FLOW 4727#

ALL WATER RATES CORRECTED FOR CONDENSER LEAKAGE

1	142.
2	143.
3	142.
4	137.
5	135.
6	137.
7	141.
8	143.
9	141.
10	142.
11	144.
12	143.
13	142.
14	139.
15	141.
16	139.
AV.	140.7

[illegible] 3
March 6, 1907
Began 2.00 P.M.
Ended 3.00 P.M.

Commonwealth Electric Co
Test of Turbine Unit No 1
INVESTIGATION OF THE EFFECT OF VACUUM UPON THE ECONOMY OF A 5000 K.W. TURBINE

Fisk St Sta. Chicago Ill
Object of Trial Vacuum Curve
General Conditions 5000 K.W.
26.5" Vacuum Barometer "29.70" Hg

PRESSURES

No.	Time	Turbine	Turbine	Turbine	Condenser	Condenser	Condenser	Condenser	Condenser	Condenser	Condenser	Condenser	Condenser
1	2.00	177	177	1.2	26.45	26.65	3.05	26.71	2.99	26.95	26.59	3.11	177.
2	.04	181	182	1.2	26.45	26.62	3.08	26.68	3.02	26.92	26.60	3.10	181.5
3	.08	178	178	1.4	26.25	26.57	3.13	26.62	3.08	26.87	26.58	3.12	181.5
4	.12	174	173	1.5	26.05	26.28	3.42	26.32	3.38	26.58	26.30	3.40	173.
5	.16	175	174	1.5	26.35	26.60	3.10	26.66	3.04	26.90	26.55	3.15	173.
6	.20	175	174	1.7	26.35	26.58	3.12	26.64	3.06	26.88	26.50	3.20	175.
7	.24	176	178	1.5	26.51	26.63	3.07	26.68	3.02	26.93	26.57	3.13	176.
8	.28	179	176	1.5	26.50	26.72	2.98	26.78	2.92	27.02	26.65	3.05	179.
9	.32	178	177.5	1.2	26.45	26.78	2.92	26.83	2.87	27.08	26.68	3.02	179.
10	.36	178	178	1.4	26.35	26.70	3.00	26.77	2.93	27.00	26.61	3.09	179.
11	.40	178	177.5	1.5	26.40	26.68	3.02	26.73	2.97	26.98	26.56	3.14	179.
12	.44	179	178	1.2	26.50	26.72	2.98	26.77	2.93	27.02	26.63	3.07	180.5
13	.48	179	177.5	1.5	26.60	26.81	2.89	26.88	2.82	27.11	26.75	2.95	180.0
14	.52	177	175	1.3	26.35	26.78	2.92	26.83	2.87	27.08	26.65	3.05	177.
15	.56	173	170	1.5	26.50	26.53	3.17	26.60	3.10	26.83	26.44	3.28	173.
16	3.00	172	169	1.3	26.45	26.63	3.07	26.68	3.02	26.93	26.55	3.15	172.5

TEMPERATURES

No.	Turbine Pounds	Turbine 1st	Turbine 2nd	Condenser 1st Pass	Condenser 2nd	Condenser 3rd	Hot Well Exp.	Hot Well Feed	Cir Water Initial	Cir Water Final	Steam to Aux.
1	520	345	194.	51.	113.	116.	114.		35.1	62.	512.
2	523.	346.	198.	52.	112.	116.	114.		35.0	62.	515.
3	521.	345.	196.	52.	112.	121.	114.		34.8	60.5	518.
4	513.	347.	196.	52.	115.	121.	118.		34.8	62.	513.
5	512.	343.	189.	52.	113.	118.	114.		35.1	62.	510.
6	514.	347.	189.	52.	114.	118.	114.		34.8	62.5	510.
7	519.	345.	190.	52.	113.	117.	114.		35.1	62.	510.
8	522.	346.	192.	51.	112.	116.	114.		35.0	62.	513.
9	519.	342.	191.	51.	112.	116.	113.		35.0	62.	513.
10	521.	345.	193.	52.	114.	116.	114.		34.8	61.	514.
11	522.	346	195.	52.	112.	116.	114.		34.8	61.	515.
12	522.	344	196.	52.	112.	117.	114.		34.8	61.	516.
13	520.	343	192.	52.	111.	115.	112.		34.8	61.	514.
14	516.	343	189.	51.	112.	116.	113.		34.6	60.5	512.
15	516.	345	189.	51.	114.	118.	115.		34.8	62.	511.
16	514.	341	188.	51.	113.	117.	114.		34.8	61.	510.

SUPERHEAT / SPEED / IHP

No.	Superheat Throttle	Superheat Turbine Throttle	Superheat Turbine 1st	Superheat Turbine 2nd	Superheat Steam to Aux.	Turbine Speed	Turbine R.P.M.	Corliss R.P.M.	Corliss Ft/Min	IHP Corliss
1		142.	129.	77.	134.	25.15	754.5	69.00	345.0	79.45
2		143.	130.	81.	135.	25.15	754.5	69.00	345.0	81.25
3		142.	129.	76.	138.	25.15	754.5	69.25	346.3	80.45
4		137.	130.	74.	137.	25.10	753.0	69.25	346.3	83.70
5		135.	126.	70.	134.	25.15	754.5	69.00	345.0	76.05
6		137.	130.	70.	133.	25.15	754.5	69.25	346.3	84.45
7		141.	128.	72.	132.	25.25	757.5	69.00	345.0	81.05
8		143	129.	75.	134.	25.25	757.5	68.75	343.8	86.90
9		141.	126.	74.	134.	25.20	756.0	69.00	345.0	84.35
10		142.	129.	75.	135.	25.20	756.0	69.25	346.3	82.45
11		144.	129.	77.	136.	25.20	756.0	68.50	342.5	79.60
12		143	128.	79.	136.	25.20	756.0	68.75	343.8	84.45
13		142.	126.	76.	135.	25.20	756.0	68.75	343.8	84.20
14		139.	127.	72.	134.	25.25	757.5	68.75	343.8	83.00
15		141.	128.	70.	135.	25.25	757.5	68.50	342.5	81.40
16		139.	125.	70.	134.	25.25	757.5	68.00	340.0	81.25

KILOWATTS

No.	Time	2 Meter Method A	2 Meter Method B	2 Meter Method Total	Excitation Amps	Excitation Volts	Excitation K.W.	Net
1	2.00	2324	2540	4864	119	115	13.7	4850
	.02	2371	2634	5005				
2	.04	2341	2537	4935	118	115	13.6	4921
	.06	2301	2493	4794				
3	.08	2236	2375	4605	118	115	13.6	4591
	.10	2207	2375	4582				
4	.12	2254	2446	4700	118	115	13.6	4686
	.14	2324	2540	4864				
5	.16	2277	2493	4770	118	115	13.6	4756
	.18	2324	2540	4864				
6	.20	2348	2587	4935	118	115	13.6	4921
	.22	2301	2687	4936				
7	.24	2324	2540	4841	119	115	13.7	4827
	.26	2348	2541	4864				
8	.28	2348	2587	4935	120	115	13.8	4921
	.30	2301	2493	4794				
9	.32	2277	2469	4746	120	115	13.8	4738
	.34	2324	2587	4864				
10	.36	2324	2493	4817	118	115	13.6	4803
	.38	2348	2540	4864				
11	.40	2277	2563	4911	118	115	13.6	4897
	.42	2348	2540	4888				
12	.44	2277	2493	4770	119	115	13.7	4856
	.46	2230	2493	4744				
13	.48	2277	2493	4780	120	115	13.8	4766
	.50	2230	2399	4629				
14	.52	2277	2446	4723	120	115	13.8	4709
	.54	2254	2446	4700				
15	.56	2277	2446	4723	121	116	14.0	4709
	.58	2230	2352	4582				
16	3.00	2230	2352	4582	121	116	14.0	4568

STEAM FLOW

No.	Turbine Total	Turbine K.W.H.	Turbine	Turbine	Auxiliaries Total	Auxiliaries	Auxiliaries K.W.H.
1							
2	7770				328.0		
3	9160				3280		
4	8270				3280		
5	8015				321.3		
6	8715				321.3		
7	8580				3366		
8	8515				336.6		
9	8575				3366		
10	8360				315.0		
11	8430				315.0		
12	8285				3150		
13	8335				3213		
14	8290				2746		
15	8215				2746		
16	8045				2746		

Totals / averages row:

Section	Values
Pressures	176.7 175.9 1.4 26.41 26.65 3.05 26.69 3.01 26.99 26.57 3.13 177.2
Temperatures	518.5 344.5 192.3 51.5 112.7 117.1 114.1 34.9 61.6 512.8
Superheat / Speed / IHP	140.7 128.3 74.3 134.6 25.11 756.2 68.87 343.9 82.13
Kilowatts	4794 119. 115. 13.7 4780
Steam Flow	8371 26.27 26.46 19.14 314. 3.76 .99

REMARKS

Outside Temperature 30°F
Switch House " 75°F
Total Steam Flow 125,560#
Total Aux. Flow 4727#
All Water Rates Corrected for Condenser Leakage

COMM… SK ST. STA. CHICAGO ILL.

…ST. …JECT OF TRIAL -- VACUUM CURVE

…VAC… …NERAL CONDITIONS -- 5000 K.W.

- Vacuum 28"

PERHE…

ABINE…

REMARKS

Barometer 29.52"

Outside Temp 33.4°F.

Switch House Temp. 73.5 °F.

Turbine Room " 66.6°F.

…ndenser leakage 7800# per hr.

…eam flow corrected for condenser leakage.

Bowl	1S…
137.	11…
135.	113…
134.	11…
136.	112…
138.	113…
137.	11…
141.	11…
145.	119…
146.	118…
144.	119…
141.	117…
139.	116…
141.	118…
142.	113…
136.	112…
138.	116…
139	115

MARCH 5, 1917
1.56 P.M.
2.56 P.M.

COMMONWEALTH ELECTRIC CO.
FISK ST. TURBINE UNIT No. 1
INVESTIGATION OF THE EFFECT OF VACUUM UPON THE ECONOMY OF A 5000 K.W. TURBINE

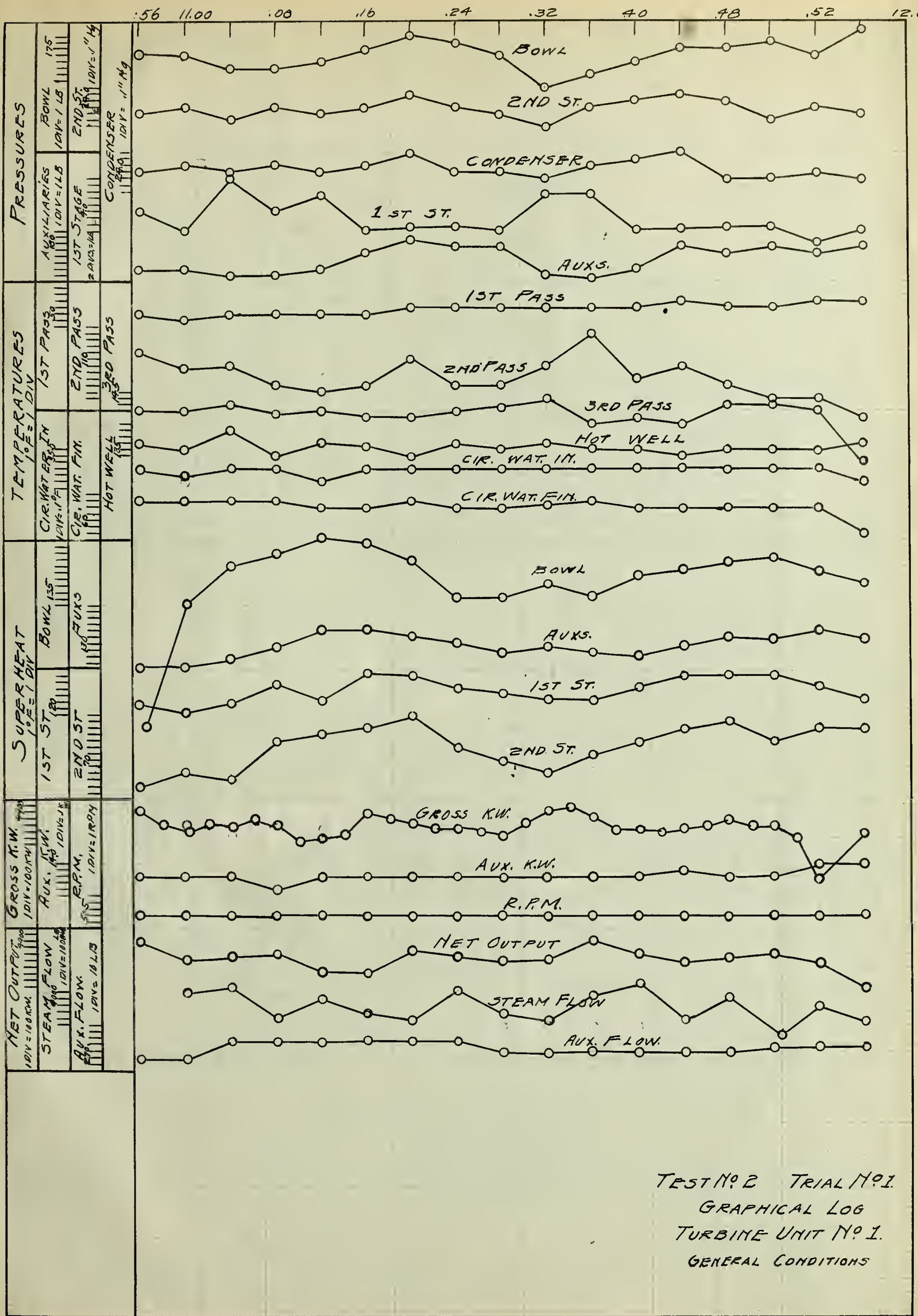
FISK ST STA. CHICAGO ILL.
OBJECT OF TRIAL VACUUM CURVE
GENERAL CONDITIONS 5000 K.W.
Vacuum 28"

No.	Time	Pressures												Temperatures: Turbine		Condenser				Hot Well		Circ. Water		
1	1.56	180.	178.	2.9	27.85	28.59	.85	28.24	1.28	28.72	28.00	1.52	182.5	515.	336.	162.	57.5	82.	91.	93.		35.	60	505.
2	2.00	177.	179.	3.4	27.85	28.64	.85	28.22	1.30	28.70	27.44	1.58	177.5	512.	335.	158.	57.	83.	91.	93.		35	60	504.
3	.04	178.	176.	2.4	27.90	28.62	.93	28.24	1.28	28.72	27.94	1.53	181.	511.5	334.	158.	57.	83.	92.5	93.		35	60	504.
4	.08	178.	175.	3.6	27.85	28.65	.90	28.22	1.30	28.70	27.90	1.62	181.	513.5	335.	157.	57.	83.5	93.	94.		35	61	504.
5	.12	180.	177.	3.7	27.85	28.70	.87	28.22	1.30	28.74	27.41	1.61	182.5	516.	336.	159.	57.5	83.	93.	94.		35	61	505.
6	.16	182.	179.	3.3	27.90	28.66	.85	28.26	1.26	28.75	27.95	1.67	184.	516.	334.	159.	57.	81.	92.	93		35	60	505.
7	.20	174.5	176.	3.1	27.93	28.59	.86	28.27	1.25	28.71	27.96	1.56	178.	519.	336.	161.	57.	82.5	92.5	92.		35	60	507.
8	.24	176.	174.	3.5	27.85	28.66	.92	28.23	1.29	28.73	27.91	1.61	178.	522.	337.	163.	57.5	88.	92.5	94.		35	60	506.
9	.28	180.	177.	3.5	27.90	28.65	.87	28.25	1.27	28.73	27.94	1.58	182.5	524.5	341.	165.	57.5	82.	91.5	93.		35	60	508.
10	.32	179.	176.	3.7	27.85	28.60	.92	28.25	1.27	28.71	27.91	1.61	181.	521.5	341.	165.	57.	83.	93.5	94.		35	61	508.
11	.36	177.	174.	4.1	27.85	28.60	.92	28.23	1.29	28.71	27.87	1.65	177.5	518.	344.	163.	57.5	84.	94.0	94.		35	61	507.
12	.40	176.5	174.	4.2	27.85	28.67	.98	28.23	1.29	28.70	27.86	1.66	178.	516.	342.	161.	58.	84.	94.0	94.		35	61	506.
13	.44	178.0	176.	3.5	27.90	28.54	.84	28.24	1.28	28.72	27.92	1.60	181.	519.	339.	163.	58.	82.5	92.	94.		35	61	506.
14	.48	180.	177.	3.7	27.90	28.68	.87	28.26	1.26	28.74	27.94	1.58	182.	520.	341.	163.	57.	82.5	92.5	94.		35	61	507.
15	.52	179.	177.	3.5	27.90	28.67	.85	28.27	1.25	28.75	27.92	1.60	182.5	514.	337.	162.	57.	82.5	92.5	94.		35	60	505.
16	.56	174.	176.	3.7	27.80	28.67	.85	28.25	1.27	28.73	27.90	1.62	178.	516.	334.	160.	58.	83.	93.	94.		35	61	505.
		178.	176.	3.5	27.87	28.64	.88	28.24	1.28	28.72	27.41	1.61	180.5	517.	338.	161.	57.5	83.	92.5	93.5		35.0	60.5	506

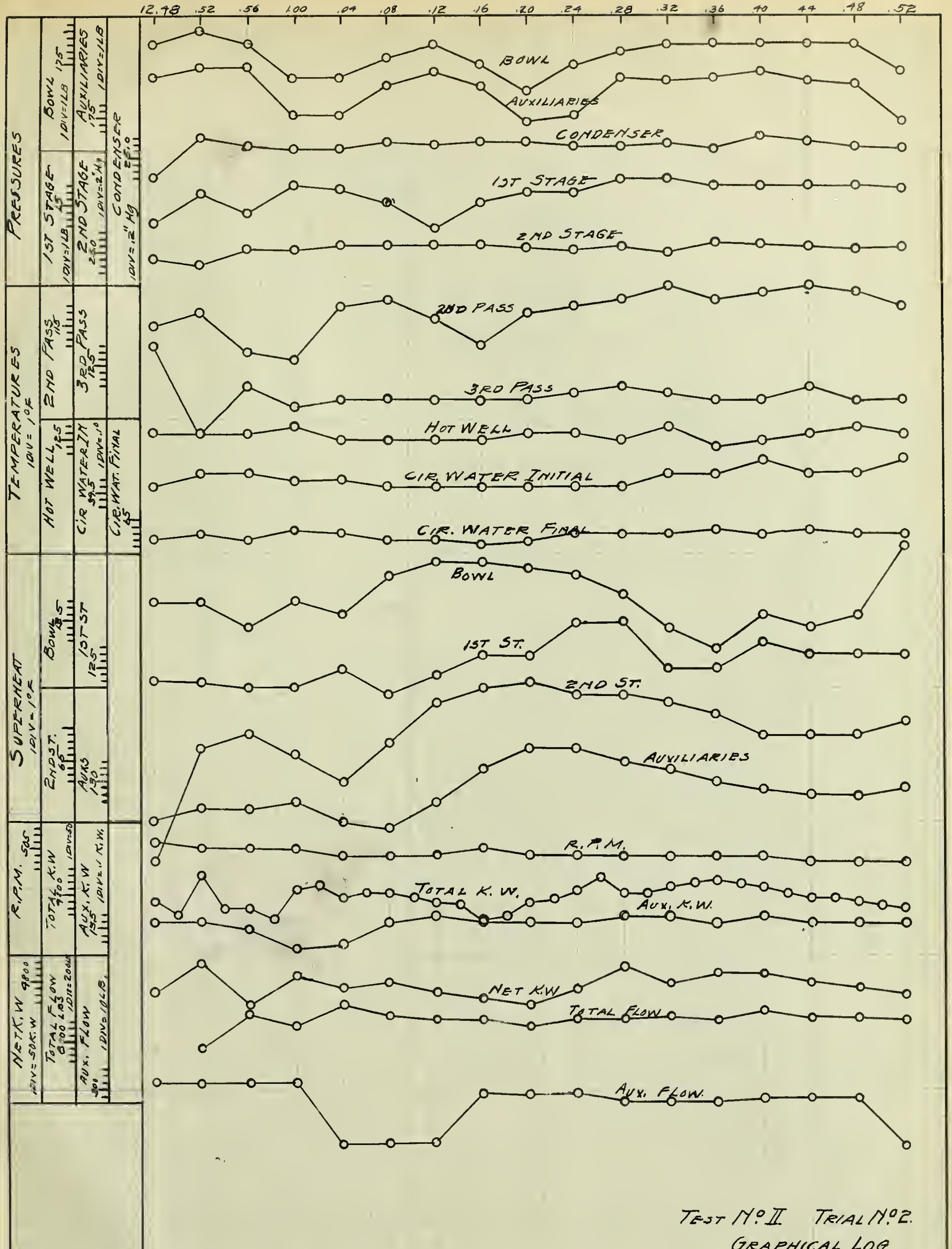
No.	Superheat: Turbine		2nd	Steam to Auxs	Speed: Turbine		Corliss		I.H.P. Corliss	Kilowatts: Time	2 Meter Method A	B	Total	Excitation: Amps	Volts	K.W.	Net	Steam Flow: Turbine Total	K.W.H.	Corrected K.W.H.		Auxiliaries: Total	% of Tur.	K.W.H.
1	137.	115.	74.	131.	25	500	69.	345	83.6	1.56 .58	2418 2418	2493 2493	4911 4911	121	116	14.0	4897							
2	135.	113.	70.	126.	25	500	68.5	342.5	81.9	2.00 .02	2371 2418	2446 2516	4817 4934	120	116	13.9	4903	8545				296.		
3	134.	113.	70.	124.	25	500	69.	345.	83.9	.04 .06	2442 2418	2516 2493	4958 4911	120	116	13.9	4944	8565				296.		
4	136.	112.	69.	124.	25	500	68.5	342.5	81.6	.08 .10	2465 2465	2516 2540	4981 5005	120	116	13.9	4967	8785				296.		
5	138.	113.	71.	125.	25	500	69.	345.	80.9	.12 .14	2442 2418	2446 2446	4888 4864	121	116	14.0	4874	8510				296.		
6	137.	115.	71.	124.	25	500	69.7	348.5	80.0	.16 .18	2325 2442	2446 2446	4841 4888	120	115	13.8	4827	8650				296.		
7	141.	115.	74.	129.	25	500	68.2	341.	79.1	.20 .22	2442 2465	2469 2446	4911 4911	120	115	13.8	4897	8410				296.		
8	145.	119.	75.	128	25	500	68.7	343.5	82.1	.24 .26	2485 2465	2493 2493	4982 4958	120	115	13.8	4868	8300				296.		
9	146.	118.	77.	129.	25	500	68.5	342.5	82.5	.28 .30	2465 2442	2493 2493	4958 4935	120	115	13.8	4944	8325				288.		
10	144.	119.	77.	128.	25	500	68.7	343.5	79.6	.32 .34	2512 2465	2540 2540	5052 5005	120	115	13.8	5038	8330				288.		
11	141.	117.	75.	126.	25	500	68.7	343.5	80.1	.36 .38	2489 2512	2540 2563	5029 5075	122	116	14.2	5015	8440				288.		
12	139.	116.	73.	127.	25	500	68.7	343.5	81.3	.40 .42	2442 2418	2446 2469	4888 4887	122	116	14.2	4874	8505				288.		
13	141.	118.	75.	128.	25	500	68.7	343.5	81.4	.44 .46	2442 2442	2446 2493	4888 4935	122	116	14.2	4874	8535				284.		
14	142.	115.	75.	128.	25	500	69.5	347.5	82.0	.48 .50	2418 2418	2446 2422	4864 4840	122	116	14.2	4850	8310				284.		
15	136.	112.	74.	126.	25	500	68.0	340.	82.1	.52 .54	2465 2489	2493 2540	4958 5029	123	116	14.2	4944	8310				284.		
16	138.	116.	72.	127.	25	500	69.2	346.	83.7	.56	2419	2540	5129	120	116	13.9	5015	8375				284.		
	139	115	73	127	25	500	68.8	344.0					4907	121	116	140.	4921	8453	26.77	26.15	19.37	290	3.4	.79

REMARKS

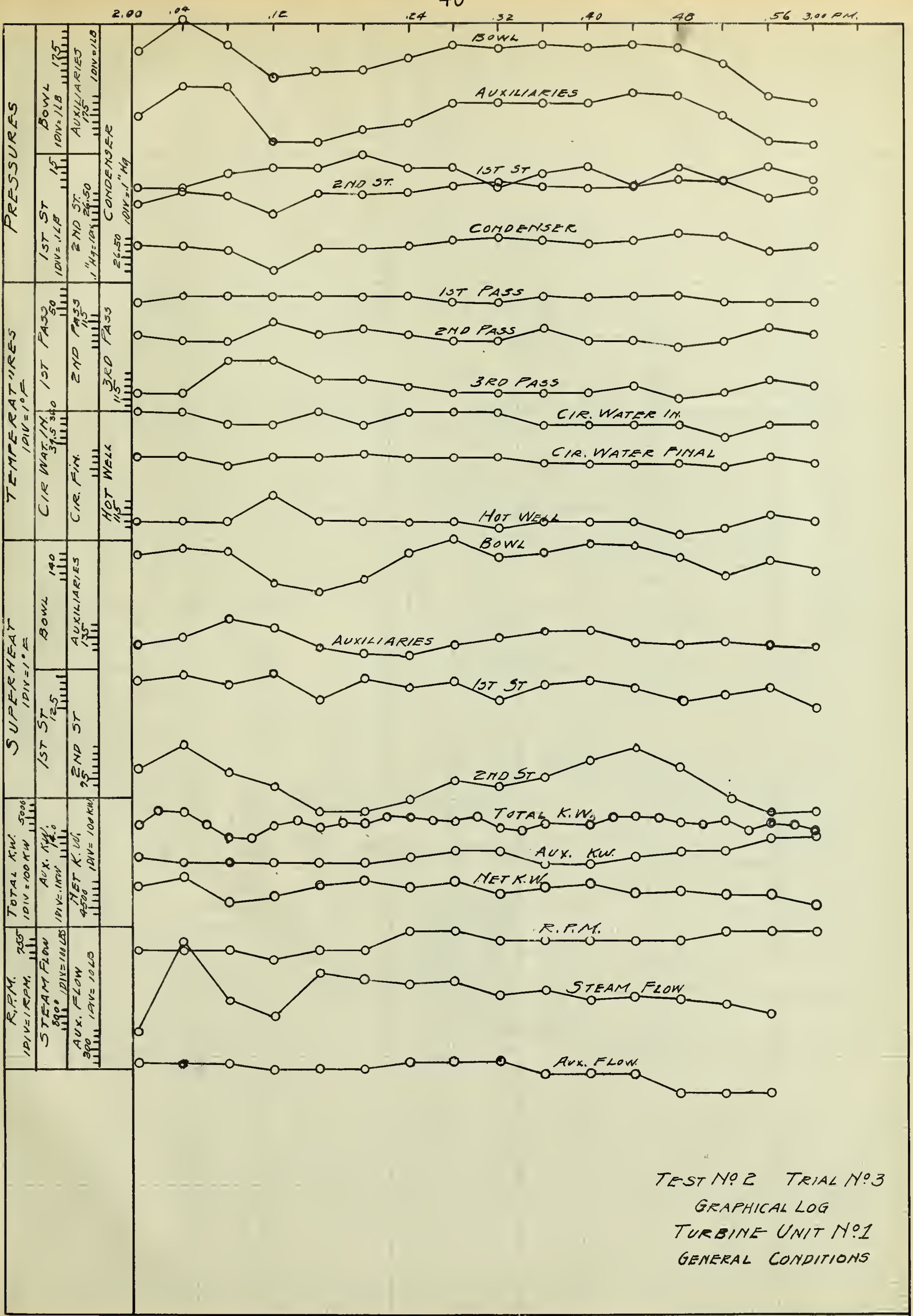
Barometer 29.52"
Outside Temp 33.4°F.
Switch House Temp. 73.5°F.
Turbine Room " 66.6°F.
Condenser leakage 1800# per hr.
Steam flow corrected for condenser leakage.



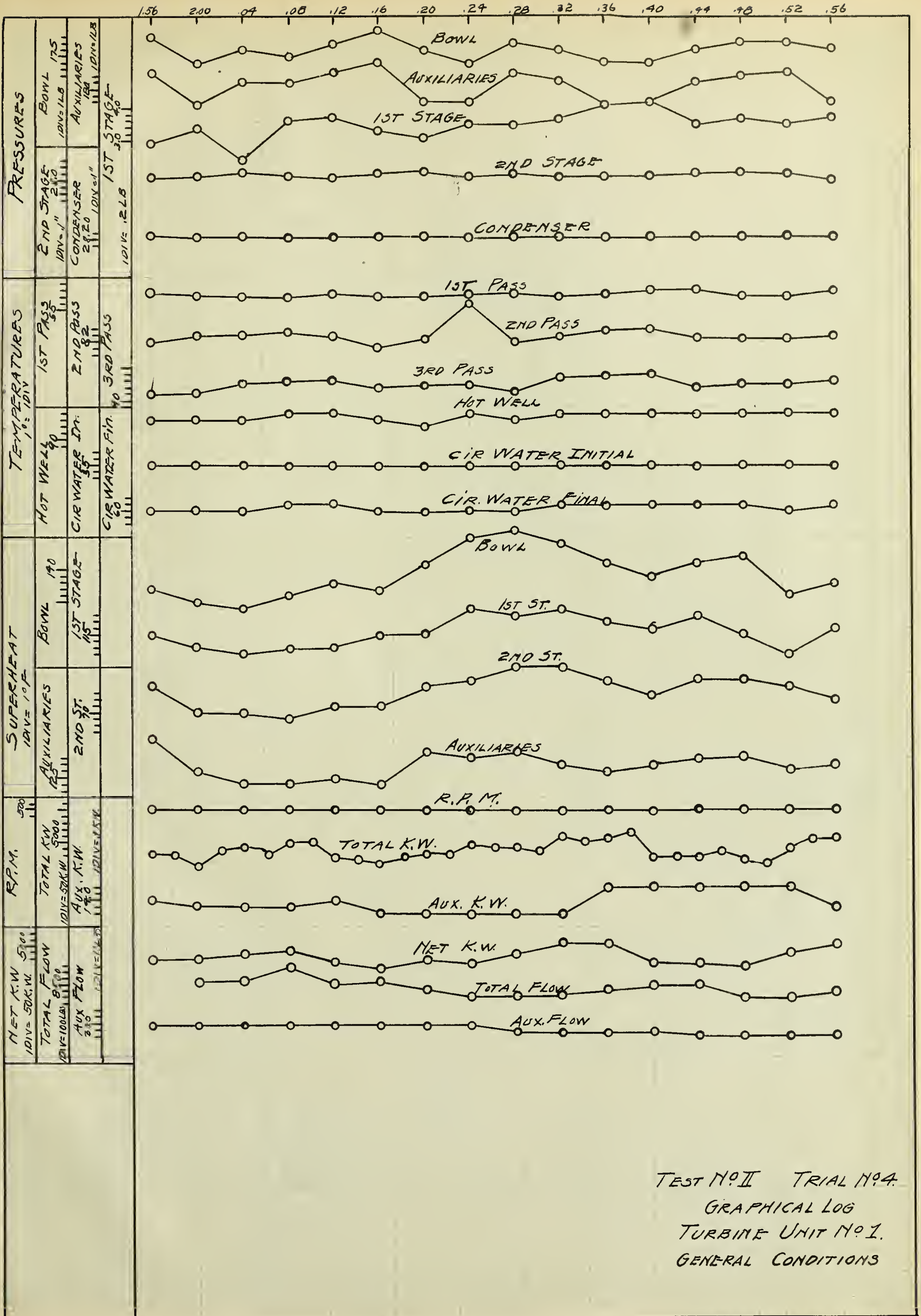
TEST Nº 2 TRIAL Nº 1
GRAPHICAL LOG
TURBINE UNIT Nº 1.
GENERAL CONDITIONS



TEST No. II TRIAL No. 2.
GRAPHICAL LOG
TURBINE UNIT No. 1.
GENERAL CONDITIONS



TEST No 2 TRIAL No 3
GRAPHICAL LOG
TURBINE UNIT No 1
GENERAL CONDITIONS


1.56
2.00
.04
.08
.12
.16
.20
.24
.28
.32
.36
.40
.44
.48
.52
.56
PRESSURES
BOWL 175 1DIV=1LB
AUXILIARIES 184 1DIV=1LB
1ST STAGE 30 40
2ND STAGE 2.10 1DIV=.1"
CONDENSER 28.20 1DIV=.1"
1DIV=.2LB
TEMPERATURES 1°=1DIV
1ST PASS 55
2ND PASS 82
3RD PASS 70
HOT WELL 90
CIR WATER IN. 55
CIR WATER FIN. 60
SUPERHEAT 1DIV=1°F
BOWL 140
1ST STAGE 115
AUXILIARIES 125
2ND ST. 70
R.P.M. 500
TOTAL K.W. 5000 1DIV=50K.W.
AUX. K.W. 140
NET K.W. 5000 1DIV=50K.W.
TOTAL FLOW 8000 1DIV=100LBS
AUX FLOW 330
BOWL
AUXILIARIES
1ST STAGE
2ND STAGE
CONDENSER
1ST PASS
2ND PASS
3RD PASS
HOT WELL
CIR WATER INITIAL
CIR. WATER FINAL
BOWL
1ST ST.
2ND ST.
AUXILIARIES
R.P.M.
TOTAL K.W.
AUX. K.W.
NET K.W.
TOTAL FLOW
AUX. FLOW
TEST No II TRIAL No 4.
GRAPHICAL LOG
TURBINE UNIT No 1.
GENERAL CONDITIONS